The Global Precipitation Measurement (GPM) Mission: An Overview

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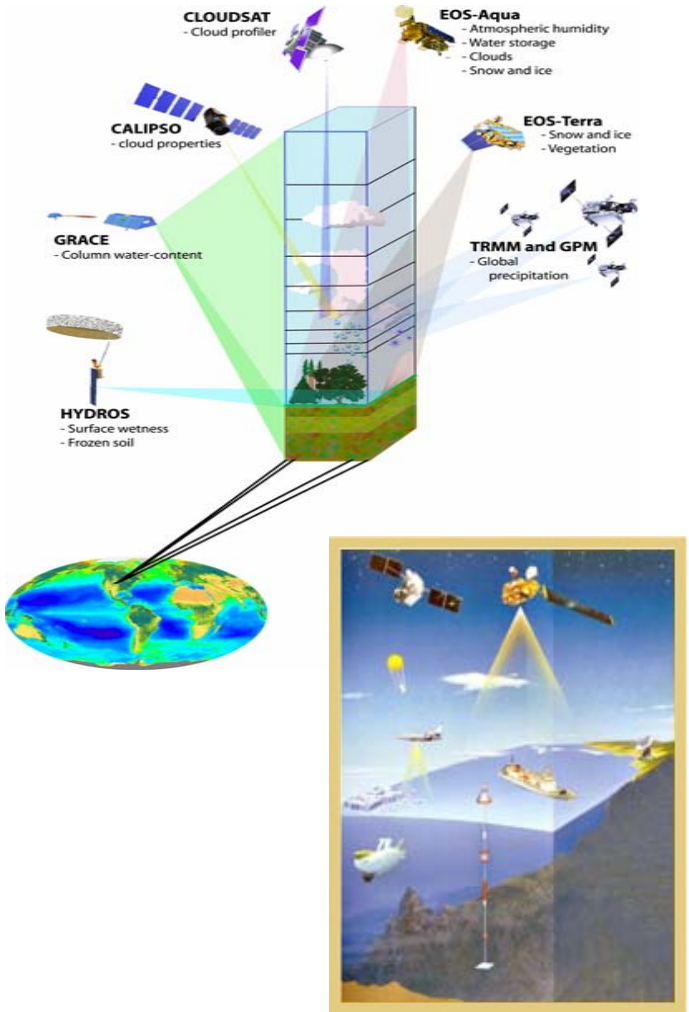
Mission Concept
Instrument Capabilities
Ground Validation
Scientific and Societal Benefits
Status

Global Water and Energy Cycle Observation Strategy



GPM

- *Flagship mission for NASA's Global Water and Energy Cycle (GWEC) research and applications*
- *Important contribution to the U.S. Climate Change Science Program & the U.S. Weather Research Program*
- *Building on*
  - the success of TRMM
  - NASA and JAXA capabilities in precipitation measurements from space
  - national and international partnerships in satellite constellation formulation and ground validation
- *Prototype for the emerging Global Earth Observing System of Systems (GEOSS), an international effort to provide comprehensive, long-term, and coordinated observations of the Earth*

GPM Science Objectives

- *Advancing precipitation measurement capability from space*

  through combined use of active and wide-band passive remote-sensing techniques

- *Advancing understanding of global water/energy cycle variability and fresh water availability*

  through better measurement of the space-time variability of global precipitation

- *Improving weather forecasting skills*

  through more accurate and frequent measurement of instantaneous rain rates

- *Improving climate modeling & prediction capabilities*

  through better understanding of precipitation microphysics, surface water fluxes, soil moisture storage, and atmospheric latent heating distribution

- *Improving prediction capabilities for floods, droughts, fresh water resources, crop conditions, & other water-related applications*

  through improved temporal sampling and high-resolution spatial coverage

A science mission with integrated applications goals.
Achieving these science objectives directly leads to societal benefits.

GPM's Dual Role in Global Precipitation Measurement – I

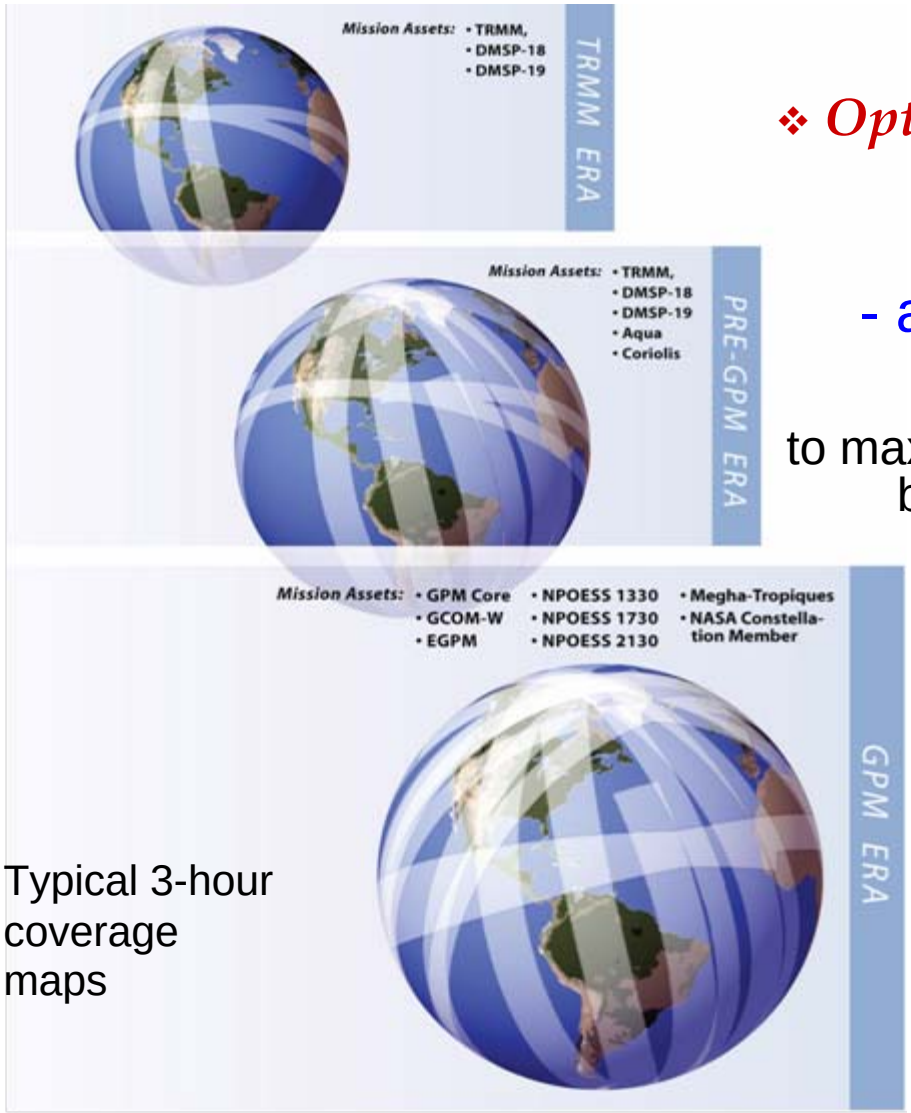
❖ ***A Reference Standard for Global Precipitation Measurement:***

GPM Core Satellite will carry

- a dual-frequency radar
- a microwave radiometer imager

to serve as *a precipitation physics observatory* and *a calibration system* for improving precipitation measurements provided by a heterogeneous constellation of dedicated and operational radiometers.

GPM's Dual Role in Global Precipitation Measurement – II



Typical 3-hour coverage maps

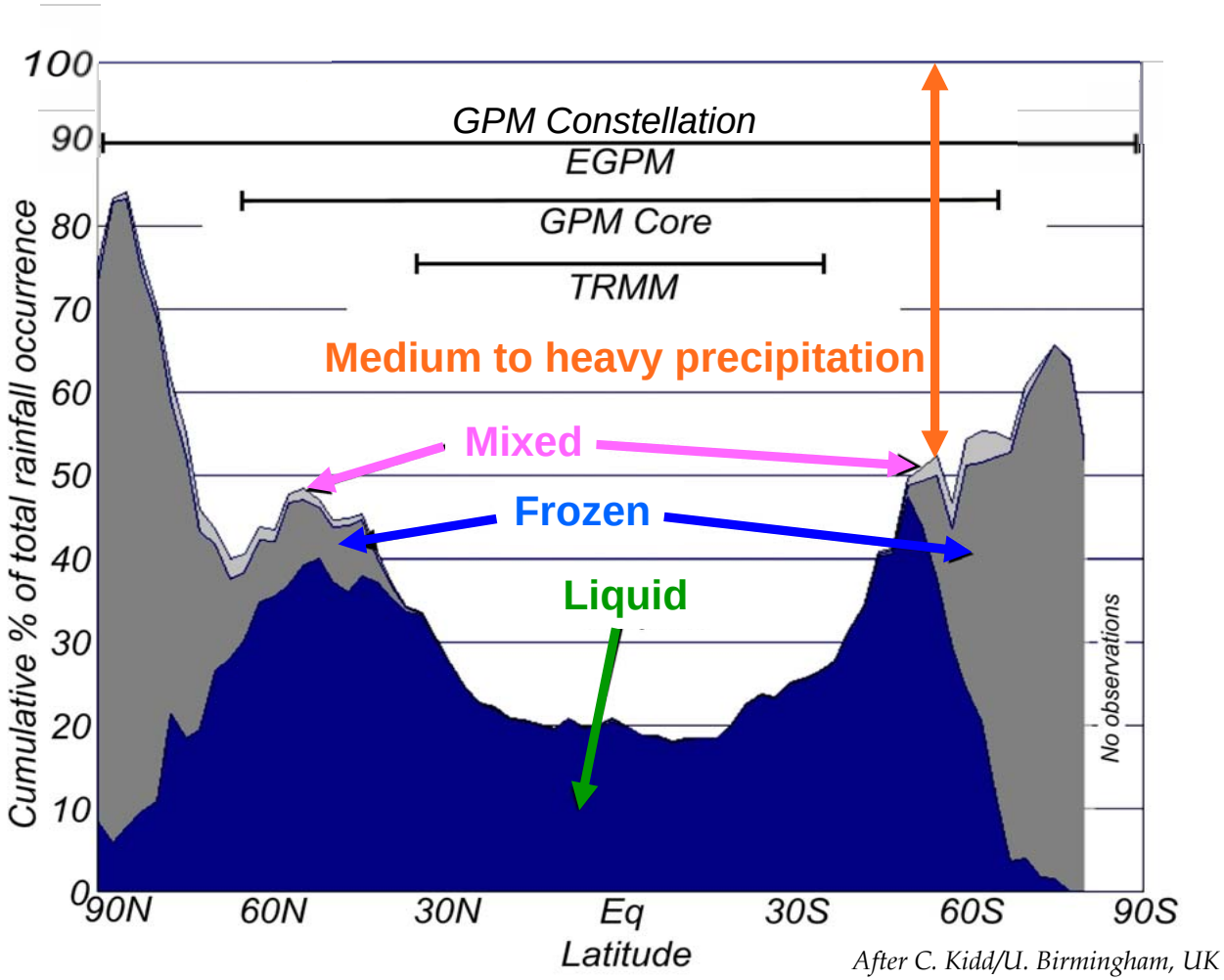
❖ *Optimization of Global Sampling:*

GPM provides

- a *"wild card" constellation satellite*

to maximize the coverage and sampling by the constellation satellites.

New Challenges: Measuring Light Rain & Snow

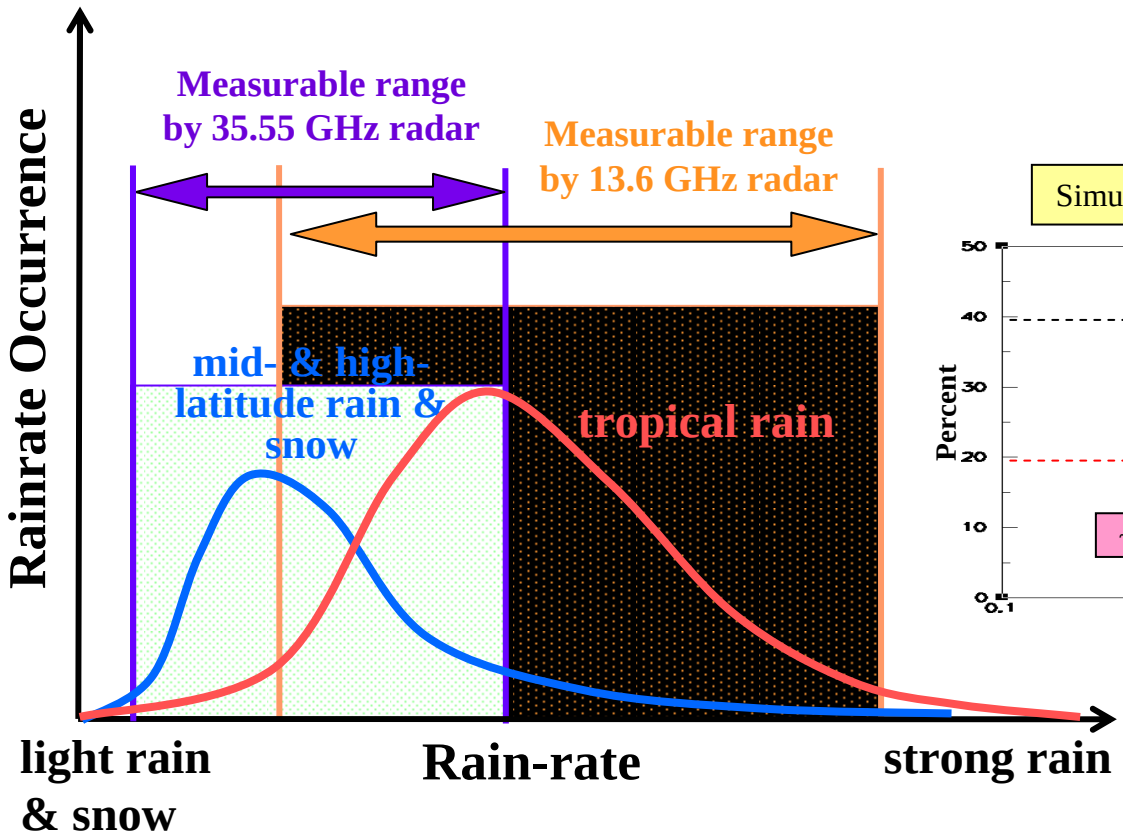


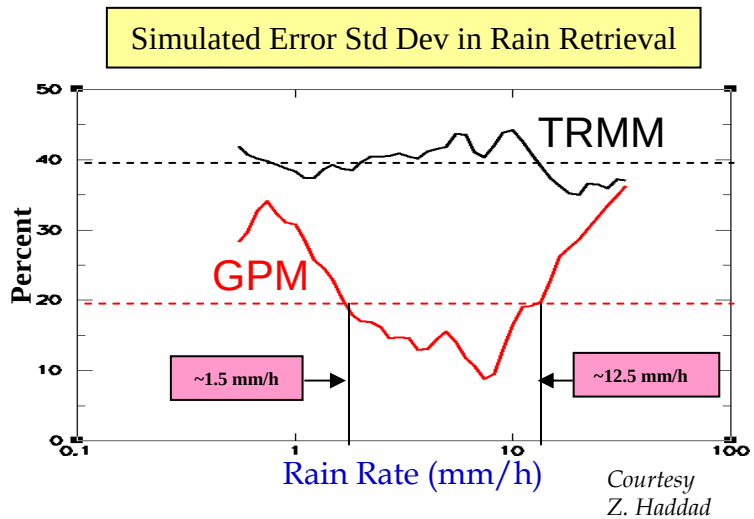
After C. Kidd/U. Birmingham, UK

Detection of light rain (< 0.5 mm/h) and snow requires greater radar sensitivity than TRMM/PR and HF (> 90 GHz) radiometer channels

JAXA/NICT Dual-Frequency Precipitation Radar

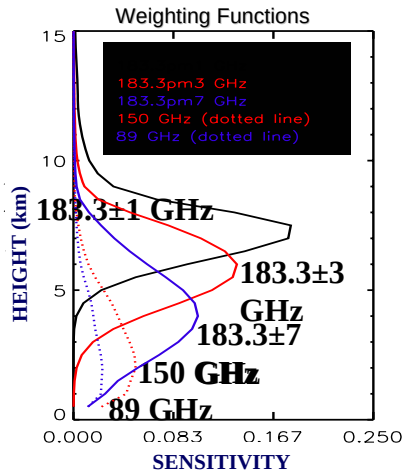
- *Increased sensitivity for light rain and snow detection* – extending the detection threshold from 18 to 11 dBZ (0.5 to 0.17 mm/h)
- *Better overall measurement accuracy* - replacing the surface reference technique for path-integrated-attenuation correction with dual-frequency methods
- *More detailed microphysical information* – estimation of drop size distribution, etc. to improve cloud database for Core and constellation radiometer retrievals



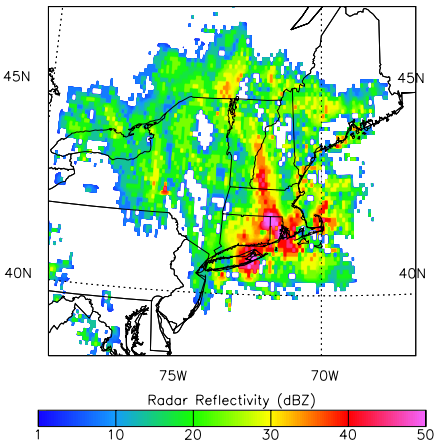


Science values of HF capability on GMI

- *Measure light rain*
- *Detect frozen precipitation*
- *Improve retrieval algorithms over land*
- *GMI HF channels on Core Spacecraft enable the testing and evaluation of constellation radiometer algorithms using the DPR*

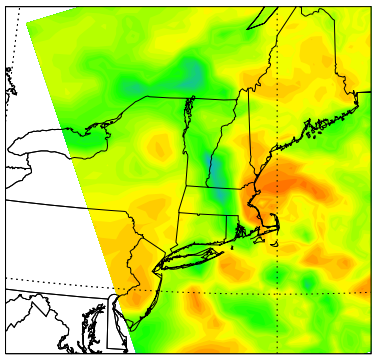


NOAA NEXRAD Data



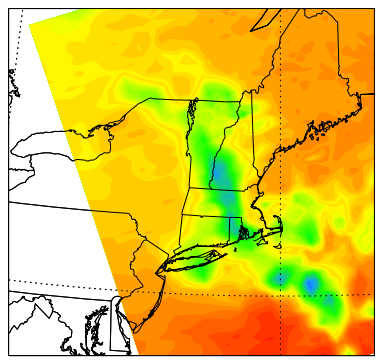
Radar reflectivity composite of the March 5-6, 2001 New England blizzard (75 cm of snow fell on Burlington, VT)

AMSU-B 89 GHz



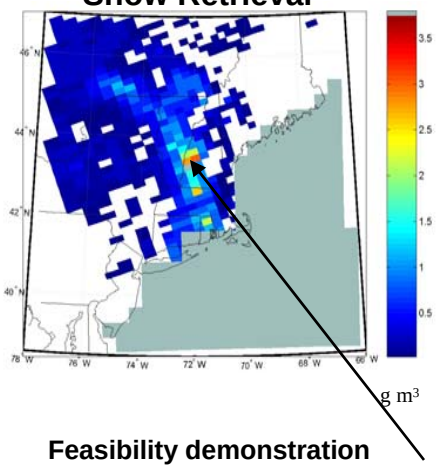
Surface effects evident over the Great Lakes, the St. Lawrence River, and along the Atlantic coast. Cannot distinguish surface from cloud effects.

AMSU-B 183.3 ± 7 GHz



Surface effects screened by water vapor. Snowfall appears over New England as low brightness temperatures

Snow Retrieval



Feasibility demonstration of snowfall retrieval using HF channels

G. Skofronick-Jackson et al. (GSFC)

GMI Characteristics Compared to Other Radiometers

Constellation radiometer assets channel coverage

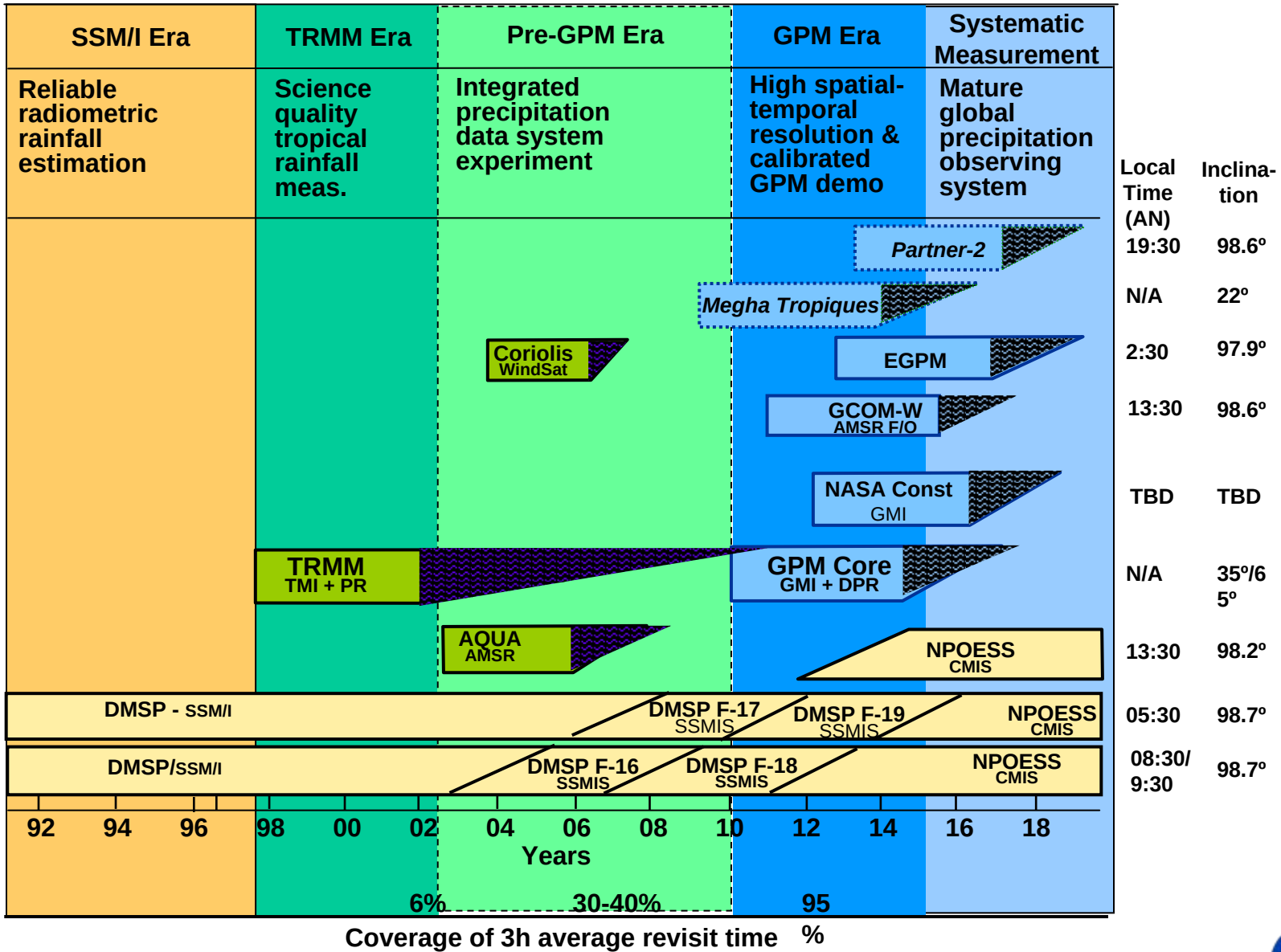
Channel	6 GHz	10 GHz	19 GHz	23 GHz	36 GHz	50-60 GHz	89 GHz	150/166 GHz	183 GHz
AMSR-E	6.925 V/H	10.65 V/H	18.7 V/H	23.8 V/H	36.5 V/H		89.0 V/H		
CMIS	6.625 V/H	10.65 H/R/L	18.70 V/P/M/R/L	23.8 V/H	36.5 V/P/H	50.3-60.44 V/L	89.0 V/H	166 V	183.31 V
GMI		10.65 V/H	18.70 V/H	23.80 V	36.50 V/H		89.0 V/H	165.5 V/H	183.31 V
MADRAS			18.7 V/H	23.8 V	36.5 V/H		89 V/H	157 V/H	
SSMIS			19.35 V/H	22.235 V	37.0 V/H	50.3-63.28 V/H	91.65 V/H	150 H	183.31H

V – Vertical Polarization **L – Left Circular Polarization**
H – Horizontal Polarization **P – Plus 45 degrees**
R - Right Circular Polarization **M – Minus 45 degrees**

Mean Spatial Resolution (km)

Channel	6 GHz	10 GHz	19 GHz	23 GHz	36 GHz	50-60 GHz	89 GHz	150/166 GHz	183 GHz
AMSR-E	56	38	21	24	12		5		
CMIS	54	38	20	15	14	14	14	14	14
GMI		26	15	12	11		6	6	6
MADRAS			40	40	40		10	6	
SSMIS			59	59	36	22	14	14	14

Improved Coverage with PMW Constellation Build-Up



GPM Ground Validation Requirements

- ***Statistical validation sites*** *for direct assessment of GPM satellite surface precipitation products:*
  - Co-located with existing or upgraded national network (NEXRAD etc.) and dense gauge networks to identify and resolve significant discrepancies between the national network and satellite estimates
- ***Precipitation process sites*** *for improving understanding and modeling of precipitation physics in physical and radiance spaces for satellite retrieval algorithm improvements:*
  - Continental tropical, mid- and high-latitude sites (including orographic/coastal sites and targeted sites for resolving discrepancies between satellite algorithms)
  - Oceanic tropical and mid-latitude sites
  - Aircraft measurements
- ***Integrated hydrological sites*** *for improving hydrological applications:*
  - Co-located with existing watersheds maintained by other US agencies and international research programs to use hydrological basins as an integrated measure of the quality of precipitation products

Sites of different categories can overlap.

Data Processing Requirements

- *Collect, analyze, distribute, and archive precipitation data from GPM Core observatory and constellation members to provide standard data products for the GPM and partner science teams:*
  - Provide orbital swath precipitation data products within 3 hours of observation at 90% of time
  - Provide 3-hourly, daily, pentad, and monthly gridded precipitation products
  - Provide a hierarchy of precipitation products ordered by retrieval quality:
    (i) combined core DPR-GMI product,
    (ii) constellation radiometer product, and
    (iii) microwave radiometer and sounder (e.g. AMSU, ATMS, etc.) product
  - Provide merged satellite microwave-IR-gauge products
- *Provide immediate precipitation products (e.g., 3-hourly rain maps - continuously updated as data arrive) to approved users for outreach activities*

Provisional GPM Data Product List

1. *Level 1 Orbital Swath Brightness Temperatures from NASA sensors (within ~15 minutes of observation at 90% of time)*
2. *Immediate Precipitation Products (e.g. 3-hourly outreach precipitation maps continuously updated as data arrive)*
3. *Level 2 Orbit Swath Products (similar to TRMM) within 3 hours of observation*
4. *Level 3 Grid Products*

   3-hourly, daily, pentad, monthly @ 0.25°x0.25°

   Simplified & integrated parameter set:
   (1) surface precipitation rate, (2) convective-stratiform separation,
   (3) latent heating profile, (4) bulk DSD parameters, (5) confidence index

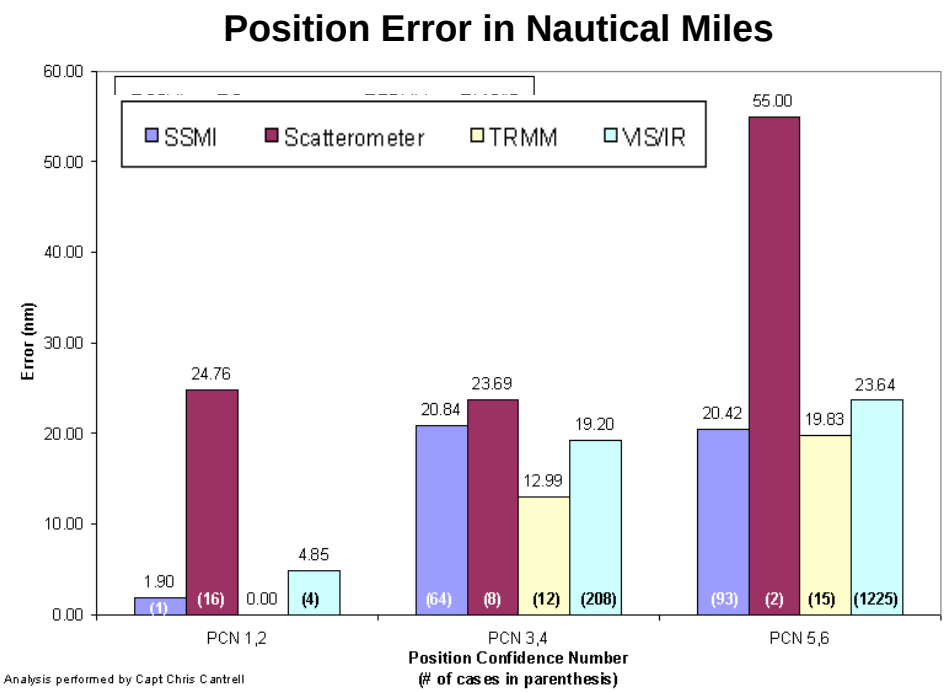
   Three types of retrieval products ordered by retrieval quality:
   (1) core (combined DPR - GMI) product,
   (2) constellation radiometer product,
   (3) microwave radiometer and sounder (e.g., AMSU, ATMS) product
5. *Level 4 Merged Satellite Microwave-IR-Gauge and/or Merged MW-IR-Gauge-Model Products*

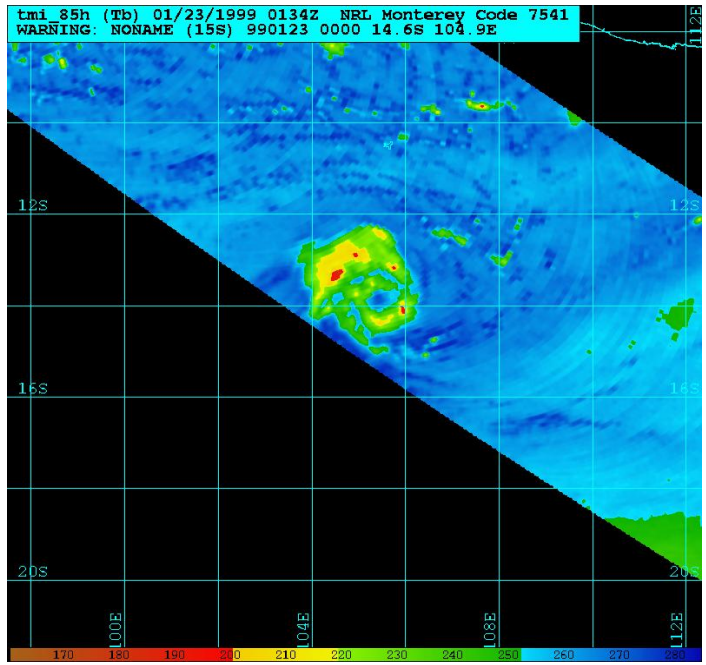
GPM Data Applications – Ia

Direct benefits of observations of precipitation intensity and structure

- Monitoring extreme precipitation events and freshwater availability
- Improving position fix for typhoon/hurricane predictions

Higher-resolution GPM radiometer data can provide better position fixes in early stages of storm development

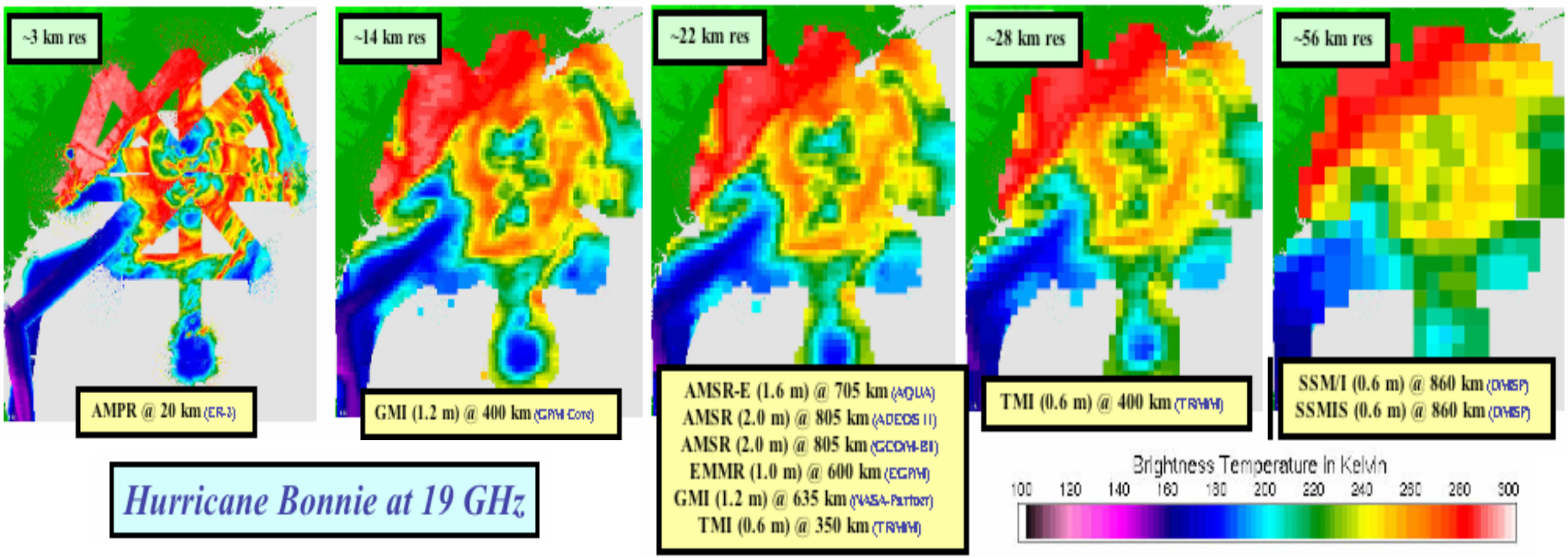




TMI 85GHz image of enclosed eye with spiral bands

GPM Data Applications – Ib

AMPR (obs) | GMI (Core) | AMSR-E | TMI | SSMIS



Hurricane Bonnie at 19 GHz

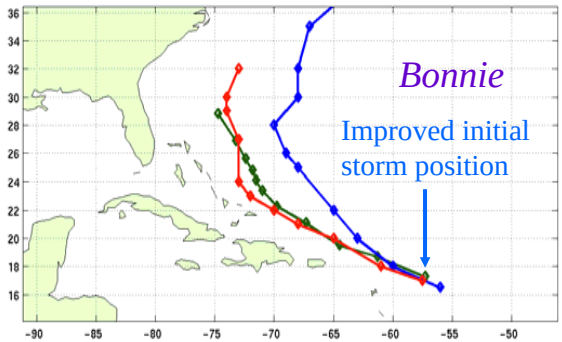
Synthesized Brightness Temperatures (R. Hood NASA/MSFC

GPM Data Applications – II

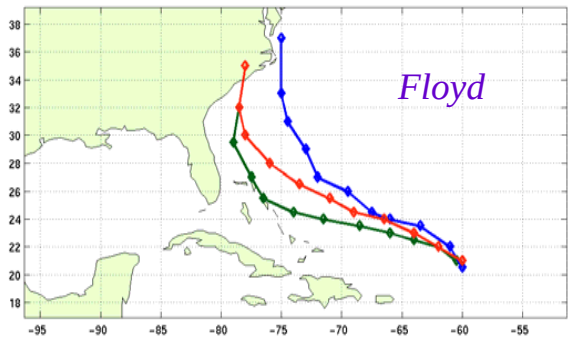
- ***Numerical Weather Prediction*** – *Provide swath brightness temperatures and rain rates to operational NWP centers to improve forecast skills*

NASA/GEOS-3 Hurricanes Bonnie and Floyd forecast improvements

5-day track forecast from 12UTC 8/20/98



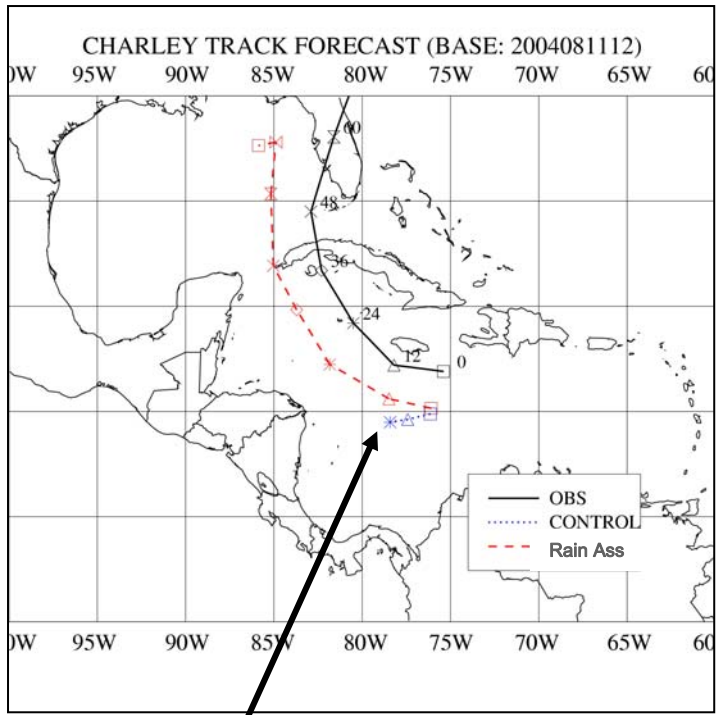
5-day track forecast from 00UTC 9/11/99



Hou et al. (2004)

Green: NOAA "observed track"
Blue: Control forecast without rainfall data
Red: With TMI+SSM/I rainfall data in IC

ECMWF Hurricane Charley track forecasts from analysis 2004081112



Operational forecast made cyclone disappear!

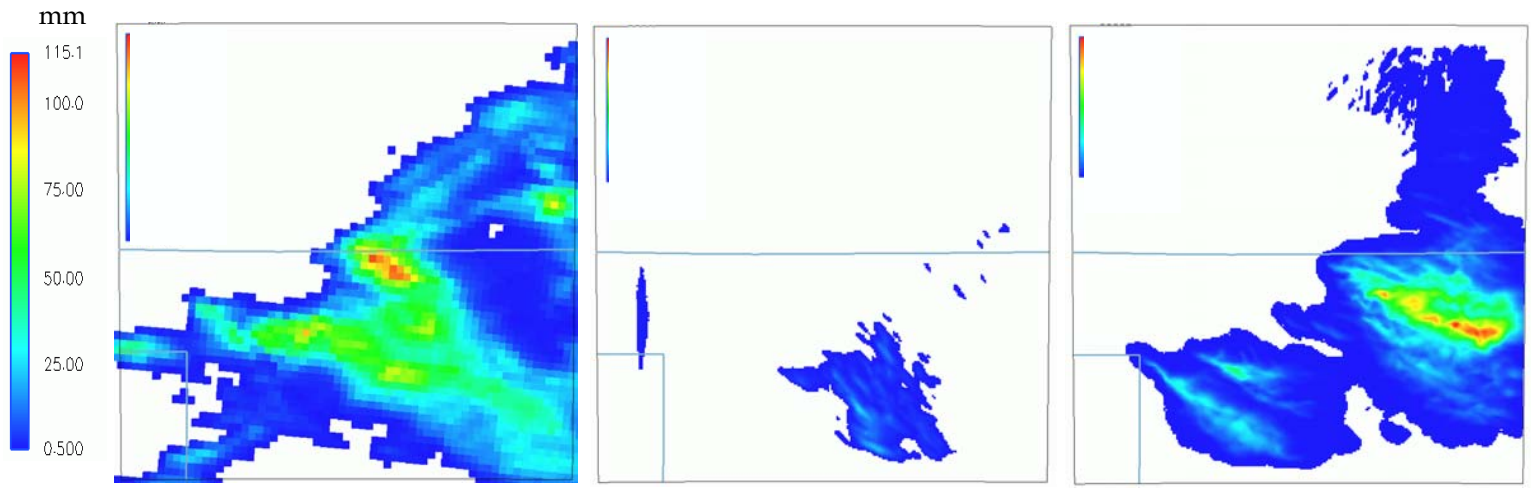
Courtesy of P. Bauer/ECMWF

GPM Data Applications – III

- ***Hydrological Prediction*** – *Provide 3-hour rainfall products to NOAA to improve operational use of satellite rainfall data in hydrological modeling and prediction*

Impact of improved soil moisture using observed surface rainfall on precipitation forecast, June 12-13, 2002

24 Hour Accumulated Precipitation (mm)



Observed radar + gauge precipitation	Mesoscale (WRF) model forecast using Land Information System (LIS) with default soil moisture initialization	WRF-LIS forecast using soil moisture derived from LIS offline spin-up using observed precipitation

Courtesy of C. Peters-Lidard/NASA

GPM Data Applications – IV

- ***Applications*** – *Make GPM data products and resources accessible to users and stakeholders beyond the traditional precipitation science community:*
  - Freshwater Utilization and Resource Management
  - Natural Hazard Monitoring/Prediction (Flood Warnings, Hurricane and Cyclone Observation, Winter Weather Events)
  - Crop Monitoring
  - Climate Change Assessment
  - Policy and Planning

- ***Outreach*** – *Make immediate precipitation data products available to:*
  - Students, teachers, and researchers in educational institutions via direct network access to GPM data products
  - Commercial and public television enterprises via near-real time graphic rain imagery
  - Any government, industrial, and academic users as well as private homes